2624

Instructions and Applications

Charge Amplifier Type 2624

The charge amplifier enables operation with accelerometers without attention to the length of cable. The Type 2624 is fully transistorised and of modular design. Frequency range extends down to 0.003 Hz.

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Charge Amplifier

Type 2624

Reprint January 1970

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1. Introduction

1.1. General

The combination of a charge amplifier and a piezoelectric accelerometer gives a sensitivity which is independent upon cable length within very wide limits. This makes a charge amplifier especially attractive in vibration systems where different cables are used. The Charge Amplifier Type 2624 may be used with cable lengths up to several thousand metres. A charge amplifier also gives possibility of very low frequency measurements and in the case of Type 2624, the limit is 0.003 Hz in the least sensitive mode, this makes the preamplifier ideal for measurements of shocks and long duration transients. The pre-amplifier is provided with an overload indicator which lights up when the dynamic range is exceeded and when the amplifier is blocked due to saturation. A reset button is used for recovery of normal working conditions after overload.

The output may be scaled to 0.1, 1 or 10 mV/pC giving different low frequency limits. See specifications. Input and output sockets are microsockets 10–32 NF and the preamplifier is completely protected against overload and short circuit.s

N.B. The Type 2624 Charge Amplifier is not recommended for use in the feedback loop of a control system, due to the blocking action after overload.

1.2. Charge Amplifier

The Type 2624 Charge Amplifier has been designed for use with piezoelectric accelerometers, where it is required that the measuring system be independent of the cable length connecting the accelerometer to the preamplifier.

The active elements of the B & K piezoelectric accelerometers are small discs of polarized ceramic which when deformed mechanically, develop a charge across opposite faces of the discs. The equivalent circuit of this system can

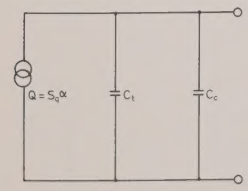


Fig. 1.1. a) Charge equivalent circuit.

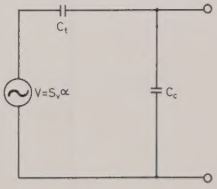


Fig. 1.1 b) Voltage equivalent circuit.

be represented either as a capacitance C_t across which a charge $S_q\alpha$ appears (Fig. 1.1a), or as a capacitance C_t in series with a voltage generator $S_v\alpha$ (Fig. 1.1b) where

S_q = charge sensitivity (pC/g)
S_v = voltage sensitivity (mV/g)
α = acceleration (g)

From the voltage equivalent circuit it can be seen that the cable capacitance C_c, and C_t act as a voltage divider, reducing the signal appearing at the other end of the cable. The cable capacitance is proportional to its length, which means that for very long cables, the voltage signal appearing at the end, and which is fed into the preamplifier is very small. Also, each time the cable length is changed, a new voltage sensitivity factor must be calculated, since the voltage divider has new component values.

If, however, an amplifier which gives an output voltage proportional to input *charge* is used, it can be seen from Fig. 1.1 a) that the cable capacitance would have no effect on the sensitivity.

This, then, is the difference between a charge amplifier and a voltage amplifier. A voltage amplifier is sensitive to variations in input *voltage* and so is sensitive to cable capacitance. A charge amplifier is sensitive to variations in input charge, and since the capacitance across which the charge appears does not alter the charge, the charge amplifier output is independent of the cable capacitance.

1.3. Principle of the Charge Amplifier

Basically, a charge amplifier consists of a high gain operational amplifier with a feedback capacitor, C_f, as in the equivalent circuit of Fig. 1.2.

It can be shown that the voltage output of this circuit is given by

$$V_o = \frac{QA}{C_t + C_c + C_f(1 - A)}$$

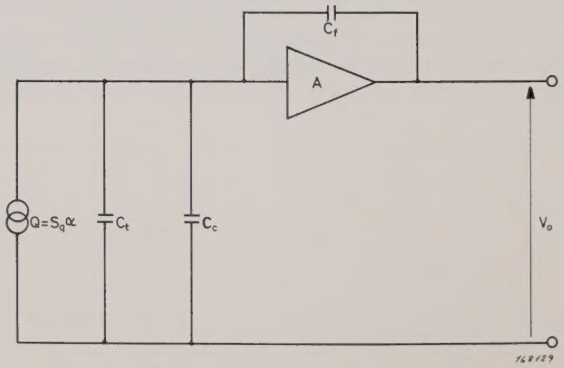


Fig. 1.2. Equivalent circuit of charge amplifier.

Since A is very large, i.e. the open loop gain of the amplifier, then usually

$$| C_t + C_c | \ll | C_f (1 - A) |$$

so the output becomes

$$V_o = \frac{Q}{C_f}$$

Hence if C_f remains constant, the output voltage is directly proportional to the charge appearing across the accelerometer, and the cable capacitance C_c normally has a negligible effect. Only when C_c becomes comparable to AC_f will it affect the gain.

1.4. Low Frequency Response

The 2624 is designed primarily as an AC instrument, but it does possess a frequency response down to approximately DC. However, low frequency measurements down to the limits of the amplifier's frequency response (0.003 Hz) require special attention. The problems involved are discussed in Section 3.7.

2. Description

2.1. Circuit

A block diagram of the circuit is given in Fig. 2.1.

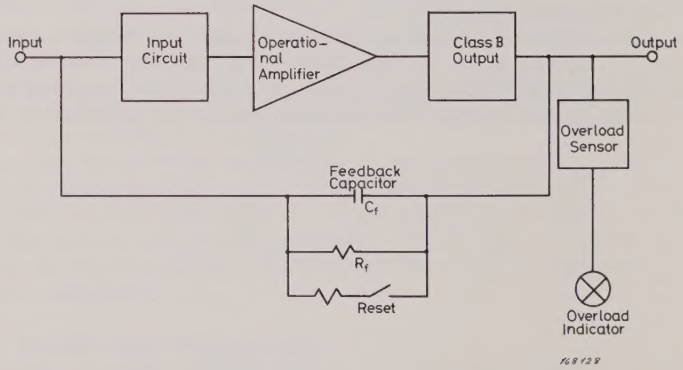


Fig. 2.1. Block diagram of preamplifier.

The input circuit has a field effect transistor, which gives the Type 2624 a high input impedance of over 10 GΩ.

The operational amplifier is followed by a class B output stage which delivers the relatively high capacitive current required by the feedback capacitors at high frequencies. A feedback resistor, R_f, is necessary for stabilization of the DC level of the amplifier, and this gives a lower limiting frequency of $\frac{1}{2\pi C_f R_f}$

The normal feedback resistor is 5 GΩ giving the lower limiting frequencies shown at the upper switch positions. These frequencies are so low that it takes a long time for restoration of normal working conditions after an accidental overload, so the 2624 is provided with a reset button which recharges the capacitors restoring working conditions immediately.

If the very low frequency response is not required, the other three positions of the sensitivity control are used, giving lower limiting frequencies 100 times higher (R_f = 50 MΩ), as marked on the instrument.

The output impedance is low, less than 1 Ω. The output is not decoupled internally, so is at about 12.5 V positive. The overload indicator lights up for both positive and negative overload.

2.2. Front panel

The front panel of the 2624 is shown in Fig. 2.2. The controls are as follows: SENSITIVITY / LOWER LIMITING FREQUENCY.

This knob has 10 positions; the four unmarked positions earth the input.

There are three charge sensitivities available: 0.1, 1, and 10 mV/pC. The upper three positions of the knob give lower limiting frequencies 100 times lower than the corresponding lower positions of the knob. All the relevant figures are marked on the front panel, and it can be seen that the frequency response can extend down to 0.003 Hz.

Fig. 2.2. Front panel.

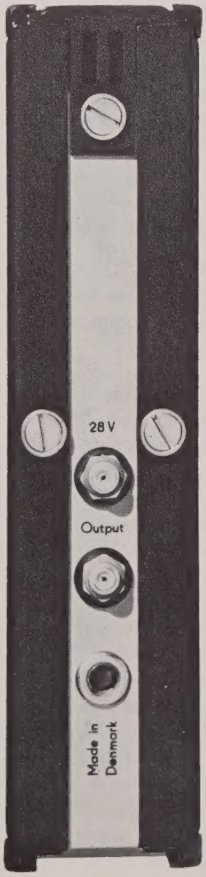


Fig. 2.3 Rear panel.

OVERLOAD
This lights up when the amplifier is negatively or positively overloaded.

RESET
Pressing this button recharges the capacitors after overload.
Whilst pressed, a 25 kΩ resistor is connected directly across the input.

INPUT
Miniature coaxial socket for connection of accelerometer cable.
Plug Type JP 0012.

OUTPUT
Miniature coaxial socket for connection of cable to analysing equipment. This connection is not DC blocked, and so is at about 12.5 V positive. This DC voltage must be either balanced out or blocked by a capacitor, although the input to most other equipments is normally blocked by a capacitor.

2.3. Rear Panel
The rear panel of the instrument is shown in Fig. 2.3.

Power 28 V
The upper miniature coaxial socket takes the lead from the power supply, with the inner conductor positive.

OUTPUT
An alternative output, connected in parallel with the output socket on the front panel.
The three screws hold the top and side panels in position.
When the screws are removed, the panels can slide off backwards.

2.4. Module System
The preamplifier is part of the B & K module system of instrumentation as shown in Fig. 2.4. This system makes rack mounting of instrument combinations very convenient.
A one tier system contains the required combination of modules mounted in the metal case KK 0010. This again fits into the wooden case KA 0020, making a portable instrument system. Standard 19″ rack mounting is simple, using the rack mounting lugs which are screwed onto the case KK 0010.
A three tier system is made up of three metal cases KK 0010 containing the required modular instruments, all mounted in the metal case KK 0011. This assembly again fits into the wooden case KA 0020.
The modules are mounted in the metal cases KK 0010 and KK 0011 as follows:

1. Loosen the finger screw in the front plate of the module and slide out the bottom plate.
2. Unscrew the feet from the bottom plate.

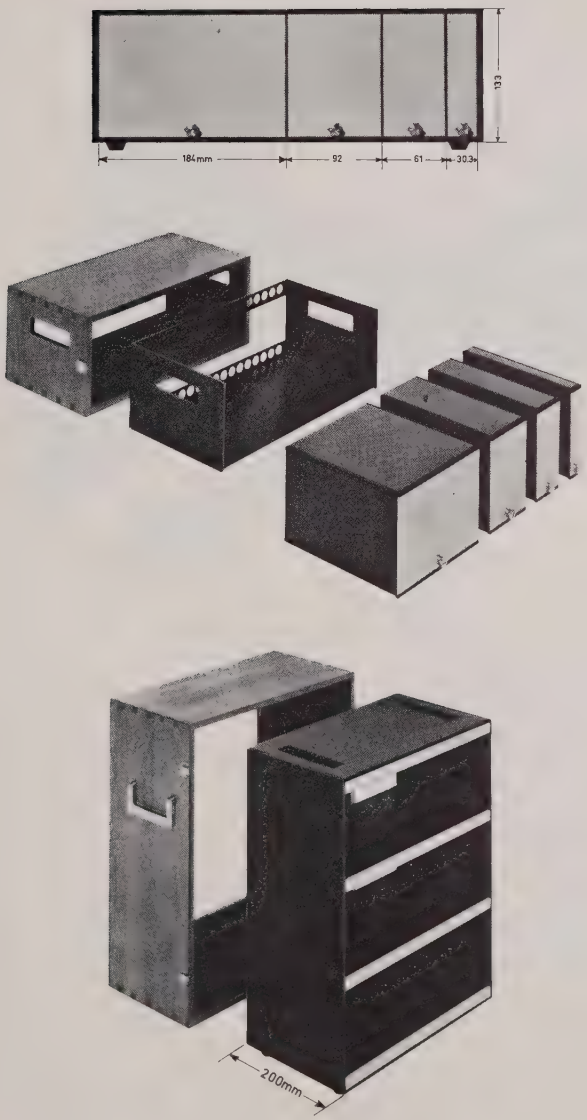


Fig. 2.4. Module system.

3. Using the same screws, fix the bottom plate inside the case KK 0010.
4. Slide the module on to the bottom plate and fix it with the finger screw.

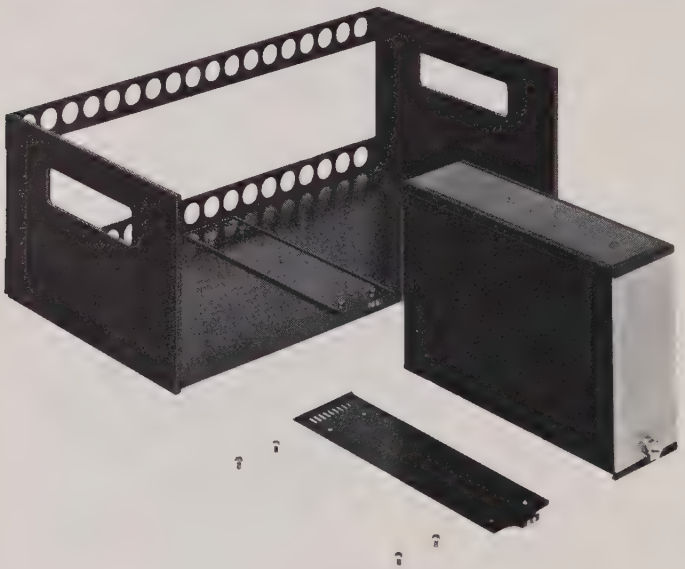


Fig. 2.5. Mounting of module.

2.5. Frequency Response

The frequency characteristics of the 2624 are shown in Fig. 2.6, for all settings of the sensitivity selector switch.

Capacitive input load causes a high frequency boost with a maximum peak at frequencies higher than 20 kHz. Under full capacitive load conditions the increase in sensitivity at 20 kHz is less than 10 %.

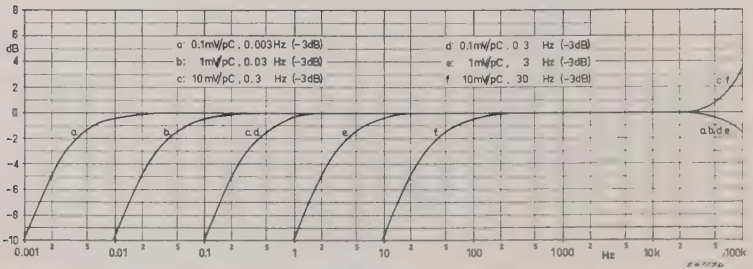


Fig. 2.6. Frequency characteristics of preamplifier for the various settings of selector switch.

2.6. Input Characteristics

Maximum Capacitive Load: 1 μF, 0.1 μF, 10 nF, respectively for the three sensitivities (0.1, 1.0, 10 mV/pC) will cause less than 1 % reduction in sensitivity.

Input DC Shunt Resistance: Greater than 10 GΩ.

With RESET button pressed, 25 kΩ ± 10 %.

2.7. Output Characteristics

Maximum voltage: 20 V peak to peak, at approx. 12.5 V DC.

Maximum current, ± 10 mA.

Output Impedance: Less than 1 Ω with less than 1/4 full input load 3–5 Ω at full input load.

The output is short-circuit protected.

The maximum current available limits the high frequency response when loaded with long cables. A set of curves for 0.5 % distortion and different cable capacity are shown in Fig. 2.7.

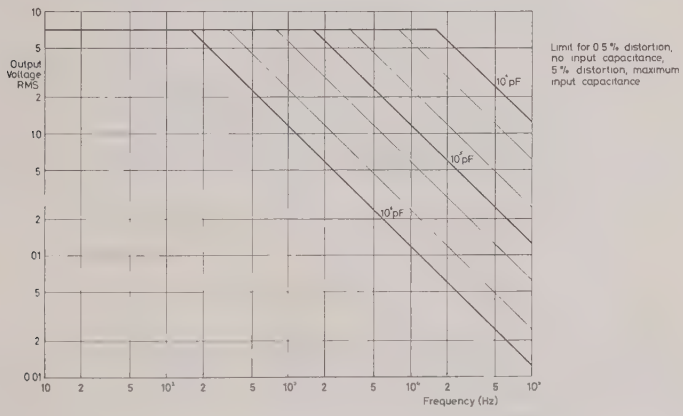


Fig. 2.7. Limit of high frequency response due to capacitive loading.

2.8. Sensitivity

The three sensitivities of 0.1, 1, 10 mV/pC are accurate to within 1 % at 100 Hz. With an accelerometer charge sensitivity of 10 pC/g, the sensitivities of the combination of amplifier and accelerometer are 1, 10 and 100 mV/g, respectively.

For the effect of input capacitance on sensitivity, see Sec. 2.6, Input Characteristics.

2.9. Harmonic Distortion

Less than 0.5 % at full output and no capacitive load, and less than 5 % at full output and full capacitive load, at frequencies below 20 kHz.

2.10. Noise

The noise level in the 2624 in the frequency range 20–40,000 Hz is shown in Figs. 2.8, 9, 10, as a 1/3 octave spectrum analysis. For each spectrum at the three sensitivities, two lengths of cable are represented, connected between accelerometer and amplifier.

Total noise voltages in the frequency range 20 Hz – 45 kHz with weighting networks, A, B, C, or linear, appear at the right hand end of the scale.

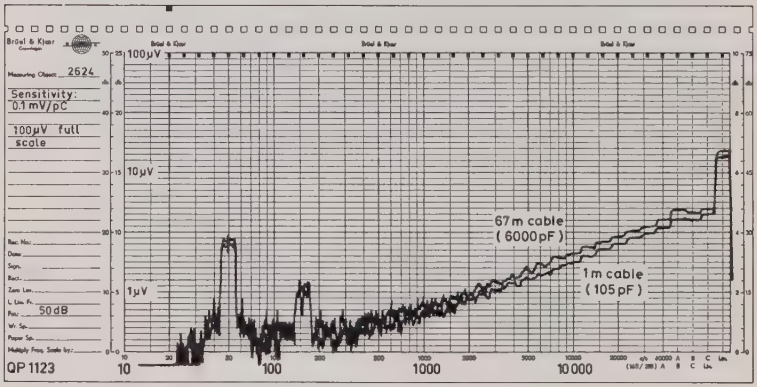


Fig. 2.8. Spectrum of inherent noise in 0.1 mV/pC mode.

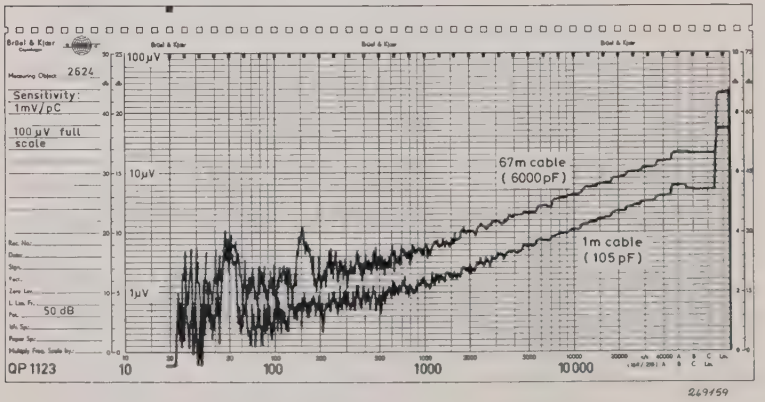


Fig. 2.9. Spectrum of inherent noise in 1 mV/pC mode.

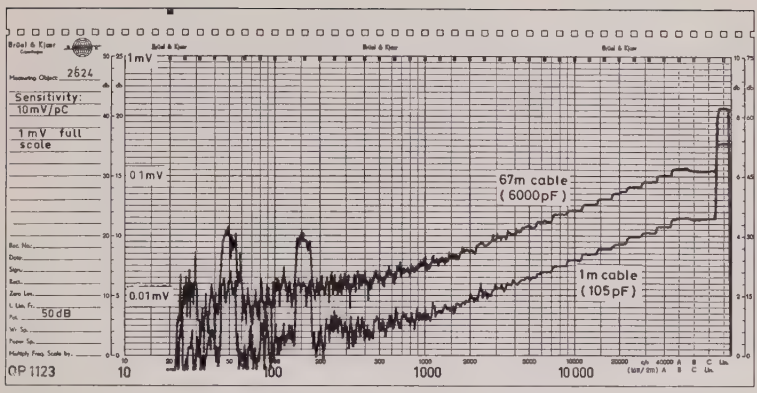


Fig. 2.10. Spectrum of inherent noise in 10 mV/pC mode.

3. Operation

3.1. Power Requirements

The 2624 must be operated from an external 28 V supply, (28 V ± 10%). Current drain is typically 17 mA; 40 mA with overload indicator lit; 150 mA max. without output terminals shorted.

Power is supplied via the miniature coaxial socket on the rear panel, using plug Type JP 0012.

3.2. Calibration Check

If an oscillator is connected to the input via a 1000 pF series capacitor, the amplifier will work as a voltage amplifier with sensitivity in V/V equal to the charge sensitivity in mV/pC.

3.3. Output Connection

Since the output must be taken via a miniature cable, an adaptor may be necessary to feed the output signal into the next instrument. See Accessories section. It must be remembered that the output is directly connected, and is thus at approximately + 12.5 V. It may be necessary to block or balance out this DC voltage. See Section 3.7.

3.4. Accelerometers

The B & K accelerometers Types 4332 – 33 – 34 – 35 – 36 – 40 are all connected via the miniature cable and plugs Type JP 0012. An individual calibration chart is supplied with each accelerometer, giving the charge sensitivity Sq. ($Sq = S_v C_{tot}$, where S_v is voltage sensitivity, C_{tot} is total capacitance of accelerometer, both including cable). At an amplifier sensitivity of S (mV/pC) the overall sensitivity to acceleration at the output of the amplifier is SSq mV/g where Sq is in pC/g.

Many accelerometers of conventional design produce low frequency voltages when subjected to temperature variations. These will be measured by the 2624 when it is used in one of the modes with an extended low frequency response. See Section 3.7.

3.5. Overload Reset

The use of this button was explained in Section 2. It should be pressed after an overload to restore operating conditions, when used in the low frequency positions.

3.6. Use in Feedback Loop of Control System

The Type 2624 is not recommended for use in the feedback loop of an acceleration control system, because of the blocking action in the event of an overload. After overload, on the lower frequency ranges, the amplifier is blocked for a long time, or until the RESET button is pressed. This would mean that no feedback was applied during this time, which could be dangerous for the vibration system.

3.7. Low Frequency Measurements

Several problems are likely to be encountered when very low frequency measurements are attempted with the 2624.

The first of these is not a problem with the amplifier but of the accelerometer. Accelerometers of normal design will give a low frequency output when subjected to temperature variations which cause variations in strain within the accelerometer. These variations in strain, if transmitted to the piezoelectric elements, will cause an output at the output terminals. Since the 2624 can have a frequency response down to 0.003 Hz, these low frequency variations will be seen at the output of the amplifier. They can be eliminated by using one of the positions of the selector knob which gives a higher low frequency cut-off. As a general rule, the position of the selector giving the highest possible low frequency cut-off should be used.

The second problem is that of the DC voltage on the output of the amplifier. The amplifier must be DC coupled if the low frequency response is to be preserved. Many measuring instruments, however, do have a capacitor input; the B & K instruments for example, give a lower cut-off frequency of 2 Hz. If a capacitor is used to decouple the output of the 2624, the lower limiting frequency will be $\frac{1}{2\pi C R_{in}}$ where C is the capacitance used and R_{in} the input resistance of the measuring instrument.

If the DC voltage (about 12.5 V positive) on the output is balanced out, problems of drift in the balancing voltage and in the amplifier power supply may arise. These are not to be confused with drift due to temperature variations of the accelerometer. Nevertheless, whatever the origin of the low frequency signal, the high frequency components on the output of the accelerometer will be correctly measured by the amplifier as long as it is not overloaded.

4. Accessories

The following accessories are available for accelerometers and preamplifiers.

UA 0125 Set of studs containing 10 isolated studs YS 0420, 10 steel studs YQ 2960, 10 nuts YM 0414, 10 mica washers YO 0534,

UA 0142 1 set of clamping magnet containing 5 permanent magnets UA 0070 with isolated mounting.

UA 0129 Set of 20 miniature plugs JP 0012 with tools and instruction for mounting of the plugs on cable.

UA 0130 Set of 25 miniature plugs JP 0012.

AO 0037 1.2 m (4 ft.) of mininoise cable for operation to 100°C (212°F) fitted with miniature plugs. Individually calibrated.

AO 0038 1.2 m (4 ft.) of mininoise cable for operation to 260°C (500°F) fitted with miniature plugs. Individually calibrated.

AC 0010 Mininoise cable up to 600 ft. in one length.
90 pF/m or 30 pF/ft., for operation to 100°C (212°F).

AC 0005 Mininoise cable up to 600 ft. in one length.
90 pF/m or 30 pF/ft., for operation to 260°C (500°F).

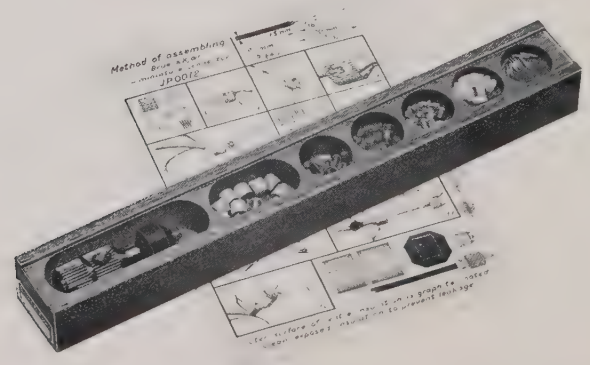
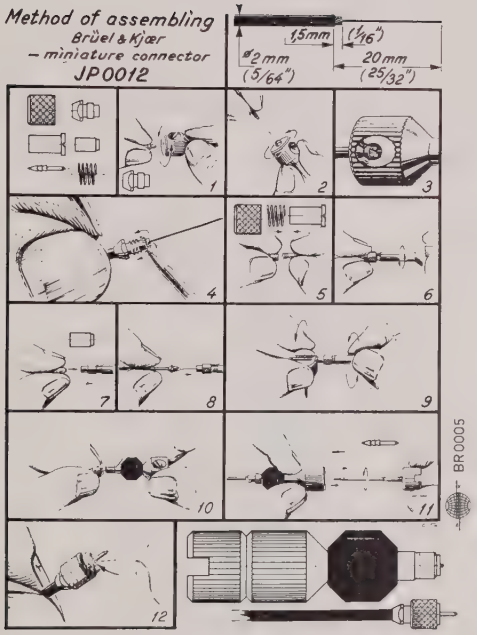


Fig. 4.1. Photograph of UA 0129 and instructions for mounting of the plug JP 0012.



Outer surface of centre insulation is graphite coated.
Clean exposed insulation to prevent leakage

5. Specifications

Sensitivity: 0.1 – 1 – 10 mV/pC ± 1 % at 100 Hz.

Input Load: Maximum 1 μF, 0.1 μF, 10 nF respectively for the 3 sensitivities, to cause less than 1 % reduction in sensitivity.

Input Shunt Resistance: 10 GΩ.
25 kΩ ± 10 % while resetting.

Frequency Range: Low frequency half power points (– 3 dB):
0.003, 0.03 and 0.3 Hz.
Alternatively 0.3, 3 and 30 Hz.
Tolerance ± 20 %.
With negligible capacitive load at input, the frequency ranges in the six positions are:

Sensitivity mV/pC	– 3 dB point, Hz	Frequency Range Hz
0.1	0.003	0.03–30,000 ± 1 %
1	0.03	0.3–30,000 ± 1 %
10	0.3	5–10,000 ± 5 %
0.1	0.3	3–30,000 ± 1 %
1	3	30–30,000 ± 1 %
10	30	150–10,000 ± 5 %

Capacitive input load causes a high frequency boost with a maximum at above 20 kHz, which is less than a 10 % increase with full capacitive input load.

Output Voltage and Current: Max. 20 V peak to peak, 12.5 V DC.
± 10 mA, short circuit protected.

Output Impedance: < 1 Ω at less than 1/4 full load.
3–5 Ω at full input load.

Harmonic Distortion: < 0.5 %, full output, no capacitive load.
< 5 %, full output, full capacitive load.
Both at frequencies < 20 kHz.

Noise: The self generated noise levels in the three ranges, referred to the output are:

0.1 mV/pC: 20 μV + max. 0.05 μV per 100 pF source capacity.

1 mV/pC: 20 μV + max. 0.5 μV per 100 pF source capacity.

10 mV/pC: 20 μV + max. 5 μV per 100 pF source capacity.

Noise bandwidth 2 Hz – 40 kHz.

Pulse Response: Without cable capacity, rise time proportional pulse height. Slope typically 1.8 Vμsec. Constant decay time, typically 2 μsec.

Overload Recovery Time: Recovery time constant = $1/2\pi f$ where f is lower limiting frequency.
Min. 5 msec, max. 50 sec.
The input is overload protected, and has overload indicator and manual reset.

Power Supply: External 28 V DC $\pm$ 10 %.
Average current drain 17 mA.
With overload indicator lit 40 mA max.
With output shorted 150 mA max.

Dimensions: (excl. knobs and feet).
Height: 132.6 mm (5.22 ins)
Width: 30.3 mm (1.19 ins)
Depth: 200 mm (7.87 ins)

Weight: 585 gm (1.29 lbs).

Accessories Included: 2 cables AO 0037 1.2 m (4 ft.) long.

B & K INSTRUMENTS:

ACOUSTICAL....
Condenser Microphones
Piezo-Electric Microphones
Microphone Preamplifiers
Microphone Calibration Equip.
Sound Level Meters
(general purpose-precision-
and impulse)
Standing Wave Apparatus
Tapping Machines
Noise Limit Indicators

ELECTROACOUSTICAL....
Artificial Ears
Artificial Mouths
Artificial Mastoids
Hearing Aid Test Boxes
Telephone Measuring Equipment
Audiometer Calibrators
Audio Reproduction Test Equip.

STRAIN....
Strain Gauge Apparatus
Multipoint Panels
Automatic Selectors
Balancing Units

VIBRATION....
Accelerometers
Accelerometer Preamplifiers
Accelerometer Calibrators
Vibration Meters
Magnetic Transducers
Capacitive Transducers
Vibration Exciter Controls
Vibration Programmers
Vibration Signal Selectors
Mini-Shakers
Complex Modulus Apparatus
Stroboscopes

GENERATING....
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators

MEASURING....
Measuring Amplifiers
Voltmeters
Deviation Bridges
Megohmmeters

ANALYZING....
Band-Pass Filter Sets
Frequency Spectrometers
Frequency Analyzers
Real-Time Analyzers
Slave Filters
Psophometer Filters
Statistical Analyzers

RECORDING....
Level Recorders
(strip-chart and polar)
Frequency Response Tracers
Tape Recorders

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